Determination of the ^{99}Tc(thermal n,γ)^{100}Tc reaction cross section from the prompt γ-ray yields

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The ^{99}Tc is one of the most important long-lived fission product nuclides (half-life: 2.1×10^5 y) contained in radioactive nuclear wastes, and is suggested as a candidate for the transmutation of the wastes using neutron-capture reactions because the reaction-product nuclide ^{100}Tc decays to the stable nuclide ^{100}Ru with a half-life of 15 s. To examine the possibility of the transmutation, it is essential to know precise values of the reaction cross section.

Several authors have measured mainly through activation methods the cross section for thermal neutrons, which are scattered in a range between 16 b and 24.3 b: there's a tendency that the old ones scatter around 20 b and the new ones close to 24 b, and the trend is reflected to the evaluated nuclear data sets.

The purpose of the present work is to determine thermal neutron capture cross section of ^{99}Tc from the yields of prompt gamma rays to the ground state of ^{100}Tc, by analyzing previously obtained experimental data which remained unanalyzed.

The (n,γ) data had been obtained at the Los Alamos National Laboratory Omega West Reactor by one of the authors and other collaborators. An enriched sample of ^{99}Tc (100 %, 84.6 mg, in metallic form) was placed in the thermal column of the internal target facility of the reactor. The target position was 1.5 m from the edge of the reactor core. At this position, the thermal neutron flux was $\sim 6 \times 10^{11} n\,\mathrm{cm}^{-2}\mathrm{s}^{-1}$, and the Cd(In) ratio is ≈ 2000.

Gamma-ray spectra were obtained with a 30-cm^3 coaxial intrinsic Ge detector positioned inside a 20-cm-diameter by 30-cm-long NaI(Tl) annulus which is optically divided into two halves. The Ge detector was located 6.3 m from the target and was operated either in the Compton-suppressed (CS) mode (0.388 keV/channel) or in the pair-spectrometer (PS) mode (0.629 keV/channel). The pulse-height analyzer had 16384 channels, and in the PS mode, gamma rays with their energies below 11.3 MeV were measured.

Energy calibrations were performed with the prompt γ-ray spectrum from neutron capture in melamine ($C_3H_3N_6$) in the PS mode, and with the prompt γ ray from the ^{1}H(n,γ) reaction plus the annihilation radiation in the CS mode. Efficiency calibrations in the CS mode were done with a set of standard radioisotopic sources with precalibrated γ-ray intensities, while in the PS mode the efficiency curve was derived from the relative intensities of γ rays from the ^{14}N(n,γ) reaction. The cross sections are normalized to the recommended value of $\sigma_\gamma(2200\ \mathrm{m/s}) = 332.6 \pm 0.7$mb for ^{1}H.

Peak-area analysis was done for each gamma ray observed both in the CS and the PS modes, and the energy as well as the intensity was determined. Combining the results of the analyses in both modes, the data were obtained of about 1100 gamma rays emitted in ^{99}Tc(thermal n,γ)^{100}Tc reaction. From the obtained data, with the help of the previously reported information on the levels of ^{100}Tc, a partial decay scheme was constructed. Among the observed gamma rays, six were assigned to transitions to the ground state, namely 172-, 223-, 264-, 341-, 356- and 459-keV ones. From the intensities of these ground-state transitions, corrected for internal conversion, the (lower limit of the) cross section is obtained as 21.37 ± 0.62 b.

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